

EVOLVED STARS AS DONORS IN SYMBIOTIC BINARIES

A. Skopal¹, M. Sekeráš¹ and N. Shagatova¹

Abstract. This contribution is focused on the role of cool giants in symbiotic binaries. Especially, we pay attention to their mass-loss rates and the wind mass-transfer onto their compact accretors.

1 Introduction

Symbiotic stars (SSs) are the widest interacting binaries, whose orbital periods run from hundreds of days to hundreds of years. They consist of an evolved red giant (RG) as the donor star and a white dwarf (WD) accreting from the giant's wind. The accretion process heats up the WD to $> 10^5$ K and increases its luminosity to $\sim 10^2 - 10^4 L_{\odot}$, which by return ionizes a fraction of the neutral wind from the giant giving rise to the nebular radiation (Seaquist *et al.* 1984, hereafter STB).

In most cases, the observed large energetic output is believed to be caused by stable nuclear hydrogen burning on the WD surface, which requires accretion onto a low mass WD at $10^{-8} - 10^{-7} M_{\odot} \text{ yr}^{-1}$ (e.g. Shen & Bildsten 2007). However, such high accretion rates cannot be achieved by a standard Bondi-Hoyle wind accretion, because of its small efficiency (Bondi & Hoyle 1944), and the mass-loss rates of $\approx 10^{-7} M_{\odot} \text{ yr}^{-1}$ from RGs in S-type SSs (e.g. Seaquist *et al.* 1993). This problem was pointed already by Kenyon & Gallagher (1983).

Accordingly, we introduce principle of methods to estimate the mass-loss rate from RGs in SSs (Sect. 2), and possible solutions of the required high mass-transfer ratio (Sect. 3).

2 Mass-loss rates from RGs in symbiotic binaries

Mass-loss rates from giants in symbiotic binaries can be determined in the context of the STB model by measuring the wind nebular emission during quiescent phase.

Supported by a grant of the Slovak Academy of Sciences, VEGA No. 2/0002/13.

¹ Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica, Slovakia

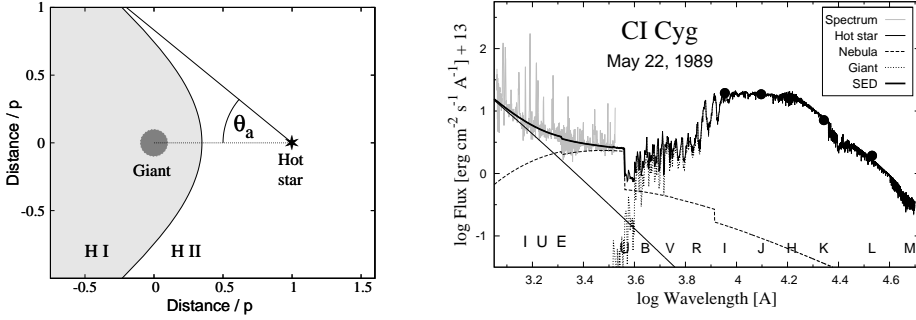


Fig. 1. The STB ionization structure (left) and corresponding SED for CI Cyg (right). Extension of the neutral zone is determined by the asymptotic angle θ_a .

The extent of the ionized RG wind is given by a parametric equation,

$$f(u, \vartheta) - X = 0, \quad (2.1)$$

the solution of which defines the H I/H II boundary at the orbital plane determined by polar coordinates (u, ϑ) centered at the hot star for a stationary binary. The parameter X is given by the binary properties and the wind mas-loss rate, \dot{M}_{RG} (see STB). Figure 1 depicts the STB ionization structure and the corresponding typical UV/near-IR SED of SSs. Measuring the radio emission at 3.6 cm for a sample of 99 SSs, Seaquist *et al.* (1993) derived $\dot{M}_{\text{RG}} \approx 10^{-7} M_{\odot} \text{ yr}^{-1}$.

In the UV/optical/near-IR, the nebular emission can be obtained by modelling the SED (see example in Fig. 1, right). On the other hand, one can calculate the nebular emission by integrating contributions throughout the volume of the fully ionized zone (see Fig. 1, left), which depends on parameters of the giant's wind. Comparing the observed and calculated continuum nebular emission, we get \dot{M}_{RG} for a given wind terminal velocity. In this way, Skopal (2005) determined $\dot{M}_{\text{RG}} = \text{a few } \times 10^{-7} M_{\odot} \text{ yr}^{-1}$ for giants in 15 well observed S-type SSs.

\dot{M}_{RG} can also be determined by probing directly the neutral fraction of the RG wind in SSs. Here, Raman scattering of the far-UV line photons on atomic hydrogen in the wind is investigated. The key parameter is the efficiency of this process, defined as the ratio between the Raman scattered and the original line photons. The Raman scattering efficiency defines the so-called 'covering factor' C_S , which represents a fraction of the sky 'seen' from the emission zone located predominately near the hot component, which is covered by the Raman scattering region. Assuming the STB geometry for the neutral zone, we can express C_S via a solid angle Ω , under which the initial line photons can 'see' the scattering region,

$$C_S = \frac{\Omega}{4\pi} = \frac{1 - \cos \theta_R}{2}, \quad (2.2)$$

where θ_R is the opening angle of the Raman scattering region. If the STB neutral zone is optically thick for Raman scattering, then $\theta_R \sim \theta_a$, which determines

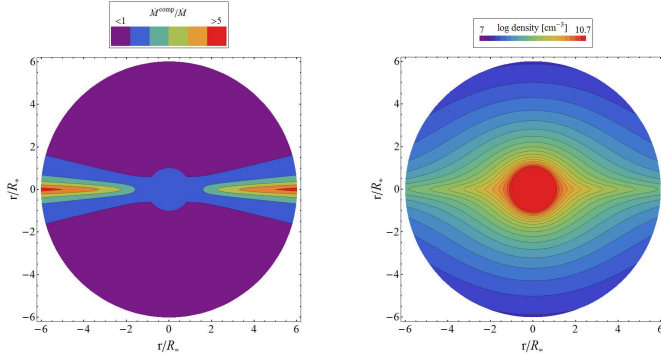


Fig. 2. Left: Compression of the wind to the equatorial plane relative to the spherically symmetric case. Right: Corresponding density distribution. Both calculated according to the wind compression model for giant’s rotation of 6 km s^{-1} , wind terminal velocity of 20 km s^{-1} , $\dot{M}_{\text{RG}} = 10^{-7} M_{\odot} \text{ yr}^{-1}$ and $R_{\text{RG}} = 100 R_{\odot}$ (see Skopal & Cariková 2015).

unambiguously the parameter X (see Fig. 1, left). Otherwise, one has to reconstruct θ_a from θ_R taking into account optically thick conditions for the investigated Raman scattering conversion. Finally, having the parameter X and the fundamental parameters of the hot component, one can derive \dot{M}_{RG} . Using Raman $\text{He II } \lambda 1025 \rightarrow \lambda 6545$ conversion we determined $\dot{M}_{\text{RG}} = 2 - 3 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$ for the mira-type variable in V1016 Cyg (see Sekeráš & Skopal, this proceedings).

3 On the mass-transfer ratio in symbiotic binaries

The long-standing problem of the large energetic output from the majority of hot components in symbiotic binaries and their deficient fueling by the RG’s wind in the canonical Bondi-Hoyle picture was recently approached in two ways.

An efficient mass-transfer mode was suggested for Mira-type interacting binaries (i.e. being in the effect for D-type SSs) by Mohamed & Podsiadlowski (2012). In this case, a slow and dense wind from an evolved AGB star is filling the Roche lobe ($v_{\text{wind}} < v_{\text{escape}}$) instead the star itself, and thus can be transferred very effectively into the potential of the companion via the L_1 point. This mass transfer mode is called *wind Roche-lobe overflow* (WRLOF).

In the case of S-type SSs, whose donors are normal RGs, an effective wind mass transfer can be caused by their rotation. Recently, Skopal & Cariková (2015) applied the wind compression disk model (WCD) of Bjorkman & Cassinelli (1993) to slowly rotating giants in S-type SSs, and found that their wind can be focused at the equatorial plane with a factor of 5–10 relative to the spherically symmetric wind (Fig. 2). This suggests a relevant increase of the accretion rate onto the WD. Investigating the hydrogen column densities, we obtained from the spectra of eclipsing S-type SSs, suggests that the wind from their RGs is really enhanced at the orbital plane (see Shagatova & Skopal, this proceedings).

4 Conclusions

Mass-loss rates from RGs in SSs are in the order of 10^{-7} and $10^{-6} M_{\odot} \text{ yr}^{-1}$ for S-type and D-type systems. The high luminosities of their accretors require an efficient wind mass-transfer mode. For D-type SSs, the WRLOF mode can be considered, while for S-type SSs, the WCD model can be in the effect.

References

- Bondi, H., & Hoyle, F. 1944, MNRAS, 114, 195
 Bjorkman, J. E., & Cassinelli, J. P. 1993, ApJ, 409, 429
 Kenyon, S. J., & Gallagher, J. S. 1983, AJ, 88, 666
 Mohamed, S. & Podsiadlowski, Ph. 2012, Baltic Astronomy, 21, 88
 Seaquist, E. R., Taylor, A. R. & Button, S. 1984, ApJ, 284, 202
 Seaquist, E. R., Krogulec, M., & Taylor, A. R. 1993, ApJ, 410, 260
 Shen, K. J., & Bildsten, L. 2007, ApJ, 660, 1444
 Skopal, A. 2005, A&A, 440, 995
 Skopal, A., & Cariková, Z. 2015, A&A, 573, A8

Discussion

J. Mikolajewska: STB model predicts the relation between turn-over frequency and orbital separation. The symbiotic star CI Cyg with very good radio spectrum (simultaneous VLA and SCUBA) shows that this model cannot be applied for the S-type symbiotic stars. Can you comment on this?

A. Skopal: STB model describes the simplest ionization structure of SSs as given by their nature. Its applicability is, however, restricted by its simplicity (e.g. stationary binary). As concerns to CI Cyg, its UV/optical/near-IR SED is consistent with the STB model (see Fig. 1).

J. Mikolajewska: SY Mus has strong ellipsoidal variability which requires much larger radius than your model suggests.

A. Skopal: The RG's radius in SY Mus of $86 R_{\odot}$ was derived from its rotation velocity assuming its co-rotation with the orbit. Similar discrepancy is indicated by other SSs, for example, FG Ser.

A. Lobel: RR Tel is an important symbiotic object, because of its very rich UV forest of emission lines from high ionic transitions. It is often used for determinations of fundamental atomic data of coronal emission lines that cannot be determined from laboratory measurements. Do you plan to measure the mass-loss rate of RR Tel as well using your method?

A. Skopal: Yes, of course. The only obstacle is to obtain its spectrum ($\delta \sim -56^{\circ}$).

A. Miroshnichenko: The wind compression model was rejected for Be stars. The disk forms only if the radiation pressure produces only radial forces. Was applicability of the WCD model tested for symbiotic stars?

A. Skopal: Yes, we tested the applicability of the WCD model to SSs in our previous papers. For example, the rotational flattening for parameters of a typical RG in SSs is only 0.975.